Cooking characteristics and consumer acceptability of bio-fortified beans

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Published by International Institute of Tropical Agriculture

May 2021

www.africa-rising.net

The Africa Research In Sustainable Intensification for the Next Generation (Africa RISING) program comprises three research-in-development projects supported by the United States Agency for International Development (USAID) as part of the U.S. Government's Feed the Future initiative.

Through action research and development partnerships, Africa RISING is creating opportunities for smallholder farm households to move out of hunger and poverty through sustainably intensified farming systems that improve food, nutrition, and income security, particularly for women and children, and conserve or enhance the natural resource base.

The three regional projects are led by the International Institute of Tropical Agriculture (in West Africa and East and Southern Africa) and the International Livestock Research Institute (in the Ethiopian Highlands). The International Food Policy Research Institute leads the program's monitoring, evaluation and impact assessment.

Africa RISING appreciates support from the American people delivered through the USAID Feed the Future initiative. We also thank farmers and local partners at all sites for their contributions to the program.

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Introduction

A bean (*Phaseolus vulgaris L.*) is the seed of one of several genera of the flowering plant family Fabaceae, which are used as vegetables for human or animal food. They can be cooked in many different ways, including boiling, frying, and baking, and are used in many traditional dishes worldwide.–Beans can either be grown as a sole crop, especially by commercial farmers, or intercropped with maize, a common practice among most subsistent farmers in Africa (Mkanda 2007). Beans provide proteins and energy in the diet for many people in rural and urban areas of Kenya, Tanzania, Malawi, Uganda, and Zambia (AGSI/FAO, 2004). Common beans also provide calcium, magnesium, vitamin B, iron, and zinc, essential for immune in human bodies. Beans are mainly cultivated by small-scale farmers as a source of income (CIAT, ICRISAT and IITA 2013).

Cooking quality in legumes includes cooking time, splitting during cooking, texture, and other sensory attributes (Mwangwela, Waniska, and Minnaar 2006). Cooking time is an essential characteristic commonly used to determine the quality of a good legume (Yeung, 2007). There is variation in bean varieties worldwide, and the variation is due to physicochemical and sensory properties (AGSI/FAO 2004). However, there are some challenges concerning beans utilization and consumption, key among them being long cooking time. Beans with a longer cooking time lead to higher energy expenses, which is not ideal for low-income communities.

Studies conducted by Scott and Maiden (1998), Ngwira and Mwangwela (2002), and Mtimuni, Ngwira, Kaponya, and Cusack (1992) showed that consumers of beans in Malawi like fast cooking beans. This makes the fast cooking time the most important characteristic in selecting bean varieties for production and consumption. Plant breeders have mainly focused on producing beans with high pest and disease resistance and high yield (Chirwa and Rubyogo 2014); however, cooking characteristics of newly bio-fortified beans have not been adequately studied. This study aimed to determine the cooking characteristics of three bio-fortified beans compared to other varieties commonly grown .

Objectives

Main objective

To determine the cooking characteristics of bio-fortified beans.

Specific objectives of the study

- To determine the moisture content of bio-fortified beans
- To determine the cooking time of bio-fortified beans
- To determine the splitting percentage of bio-fortified beans
- To determine water absorption of bio-fortified beans
- To determine the soluble solid loss (broth thickness) of bio-fortified beans
- To assess the consumer acceptability of bio-fortified beans compared to widely available local varieties

Methodology

Study area

Analysis of cooking characteristics was done at the Nutrition and Food Science Laboratory at the Lilongwe University Agriculture and Natural Resources.

Sources of raw materials

Four varieties, namely NUA 45, NUA 59, NUA35, and Napilira were collected from Chitedze Research Station (ICRISAT), and these beans were grown in the 2018 to 2019 cropping season.

Sample handling, processing, and storage

Beans were sorted to remove stones, broken and rotten seeds, and defective grains, followed by packing in plastic pails and then stored in deep freezers ready for analysis.

Sample analysis

Four bean varieties (whole and dry) were analyzed in this study. The analysis was repeated five times for accuracy and precision.

Moisture content of beans

The moisture content of bean seeds was determined according to the method of Machinjili (2018). Thirty grams of bean seeds were weighed (M0) into pre-dried moisture tins (1h, 103^{o}c) that were cooled in a desiccator. The samples were dried for 72 hours in a hot air oven at 103^{o}c. Dried samples were cooled in a desiccator and weighed (M1), moisture content was calculated as follows:

$$Moisture\ (\%) = \frac{M0-M1}{M0} x100$$

Determination of water absorption during soaking of beans at room temperature

The water absorption of bean seeds during soaking was determined by a modified method of Agbo, Hosfield, Uebersax and Kimparens (1987). Ten grams of bean seeds were placed in 100 ml Erlenmeyer flasks containing 50 ml deionized water. The Erlenmeyer flasks were placed in an incubator at 22$^{o}{}_{C}$ for 1, 2, 3, 4, 5, and 6 hours. The excess water was drained using a metal sieve (2.5mm) at each interval, and the beans were then blotted dry with absorbent paper to remove excess water and afterward weighed. Five replicates, each done in duplicate, were used. The mean of gain in weight of soaked samples was expressed as a g water kg^{-1} beans corresponding to water absorbed (WAS) according to the following formula:

$$WAS= \frac{weight\ of\ the\ sample\ after\ soaking\ -\ the\ weight\ of\ the\ sample\ before\ soaking}{Weight\ of\ the\ sample\ before\ soaking}$$

Determination of water absorption during cooking of beans

The amount of water absorbed during cooking was determined using Cenkowski and Sosulski (1997) method. For each variety of beans, approximately 10g of beans were placed in 100 ml Erlenmeyer flasks containing 50 ml deionized water. The Erlenmeyer flasks were placed in a heavy aluminium pan containing 3000 ml of deionized water. The pan was tightly covered and brought to boil, allowing 5min for heating up. The beans were cooked for 30, 60, 90, 120, 150, 180, 210, and 240 minutes. After cooking, two sample flasks per bean variety were removed, and excess water was drained using a metal sieve (2.5mm). The beans were cooled to room temperature for 1 hour, blotted dry with absorbent paper to remove excess water, and weighed. The gain in weight (g) was expressed as a g water kg^{-1} bean.

$$WAC = \frac{\text{Weight of the sample after cooking} - \text{weight of the sample before cooking}}{\text{Weight of the sample before cooking}}$$

Determination of splitting during cooking of beans

The splitting of seeds during cooking was determined according to the method of Van Buren, Bourne, Downing, Quele, Chise and Comstock (1996). The bean seeds with split seed coats and cotyledons were counted as splits. The degree was calculated as follows:

$$\frac{\text{Number of split seeds}}{\text{Number of whole seeds}} \times 100$$

Determination of the cooking time of beans

Cooking time was determined according to the Mattson method that was later modified by Jackson and Variano Martson (1981) using Mattson cooking device. The apparatus has a cooking rack (Mattson cooker) with 25 rods 49.8g each and 25 cylindrical holes (nine-millimetre diameter) where seeds were placed. The piercing tip of each rod was put in contact with the surface of the seed. The Mattson cooker was placed into a stainless-steel pot containing about 3000ml of boiling deionized water. When the bean seed was sufficiently tender, the piercing tip penetrated the cooked seed, and the rods dropped through the hole in the saddle (Jackson and Variano Marston 1981). The cooking time was recorded when 20 rods (80%) had fallen through the cooked seeds.

Determination of total soluble solids (broth thickness) of beans

Broth thickness was measured by determining the total soluble solids in the broth by oven drying the broth. The crucibles were dried in an oven for two hours at 80°C and allowed to cool to room temperature. The dry crucibles were weighed, and the weights were recorded as 'the empty crucible,' 15 ml of broth was transferred into the weighed crucible and weighed. The weight was recorded as 'crucible + broth.' The crucibles with broth were placed in a drying oven set at 105 ºC for 16 hours for the sample to dry. The crucibles with dry broth were removed from the oven with tongs and placed into desiccators to cool. The dry crucibles were then weighed with solids remaining from the broth. The weight was recorded as 'crucible + dry broth.

Sensory evaluation using Check All that Applies (CATA) of Bio-fortified Beans

Sensory evaluation of bio-fortified beans was conducted in Linthipe EPA in the following villages: Mbidzi, Nkhanganya and Nkuwazi. Purposive sampling was done to select farmers who grow bio-fortified beans and are beneficiaries of the Africa RISING project. In each village, 50 panelists/respondents were selected purposively, making it to 150 panelists in this study. Four bean varieties (NUA 59, NUA 59, NUA 35, and Napilira were tested by each panelist. One sample was presented at a time. CATA tool was used in this sensory., Panelists were presented with all attributes associated with dry beans and were asked to choose which attribute applies; after that 5-point hedonic scale was used to assess their liking level, one representing immensely dislike, and five representing extremely like. Lastly, panelists were asked to rank the bean samples from number one up to number four in their preference.

Sample preparation during sensory evaluation of beans

Beans (500 g) of each variety were cooked using firewood in an open space. Beans were cooked for 3 hours. All the bean varieties were cooked simultaneously, with the same amount of water, and using firewood. Two grams of salt was added 15 minutes before the end time of cooking. Each panelist was given 20 g of each bean variety served using transparent bowls and spoons, with blind codes of 3 digits. Bean samples were placed on a white tray with a glass of water for cleansing the mouth before and in between tasting each sample. Samples were served in a block design.

Data analysis

Data were entered in Microsoft Excel and then analyzed on GenStat version 15. Analysis of variance was determined for all parameters. Significant means were separated using the Least Significant Difference (LSD) at $P < 0.05$ level of confidence. Data analysis was done in XLSTAT (ver 19.01; Addinsoft, New York). Data for hedonic one-way (ANOVA) was used, and Tukey's honestly significant difference (HSD) test was used for means separation. Cochran's Q test followed by McNemar's (Bonferroni) method for pairwise comparisons was used to analyze CATA data. The mean impact was analyzed to assess the effect of the CATA responses on the overall liking mean scores of the samples. Principal Component Analysis (PCA) was used to determine the attributes that are associated with bean varieties.

Results and discussion

Cooking characteristics of biofortified beans

The moisture content of beans

Moisture content was high in NUA59 bean variety, followed by NUA 45 and then Napilira. NUA 35 had the lowest moisture content (7.72%). The results showed no significant difference in moisture content at p-value 0.05, as shown in Table 1 below.

Table 1: Moisture content of dry beans

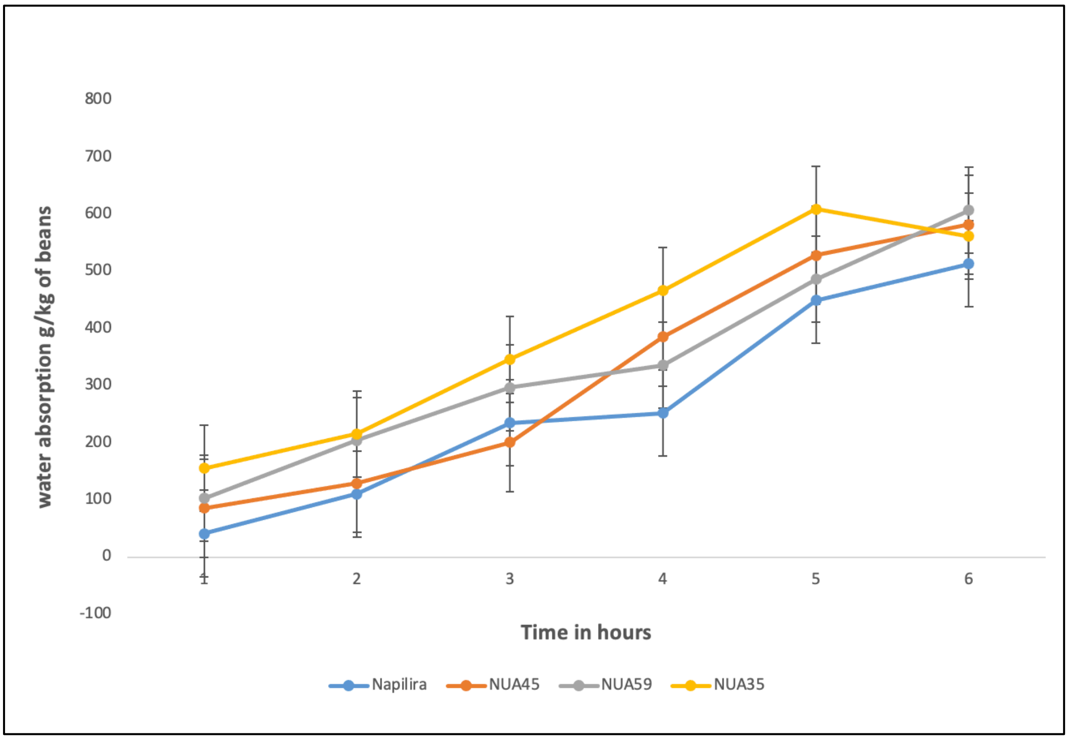
Bean variety	Moisture (%)
NUA59	$8.30^{a} \pm 0.74$
NUA45	$8.19^{a} \pm 0.29$
Napilira	$7.84^{a} \pm 0.19$
NUA35	$7.72^{a} \pm 2.03$
P-value	*0.978*

Values followed by different superscripts in one column indicate a significant difference (P<0.05) Mean ± Standard error

Altuntas and Demirtola (2010) reported the moisture percentage of a whole dry black-eyed pea, pea, and kidney beans to be 8.21%, 8.20%, and 5.66%, respectively. The moisture content percentage found in this study is within the range of typical dry legumes, which is 5% to 16 %. Low moisture content suggests a relatively long shelf life of commodities (Ade-Omowayele, Tucker and Smetanska 2015).

Water absorption of beans during soaking

There was an increase in the amount of water absorption per kilogram of Napilira, NUA 45, NUA 59, and NUA 35 with increasing soaking time, as shown in figure 1. NUA35 (608 g of water/kg) showed to absorb more water than other varieties. Napilira (513 g of water/kg) had the lowest water absorption capacity.



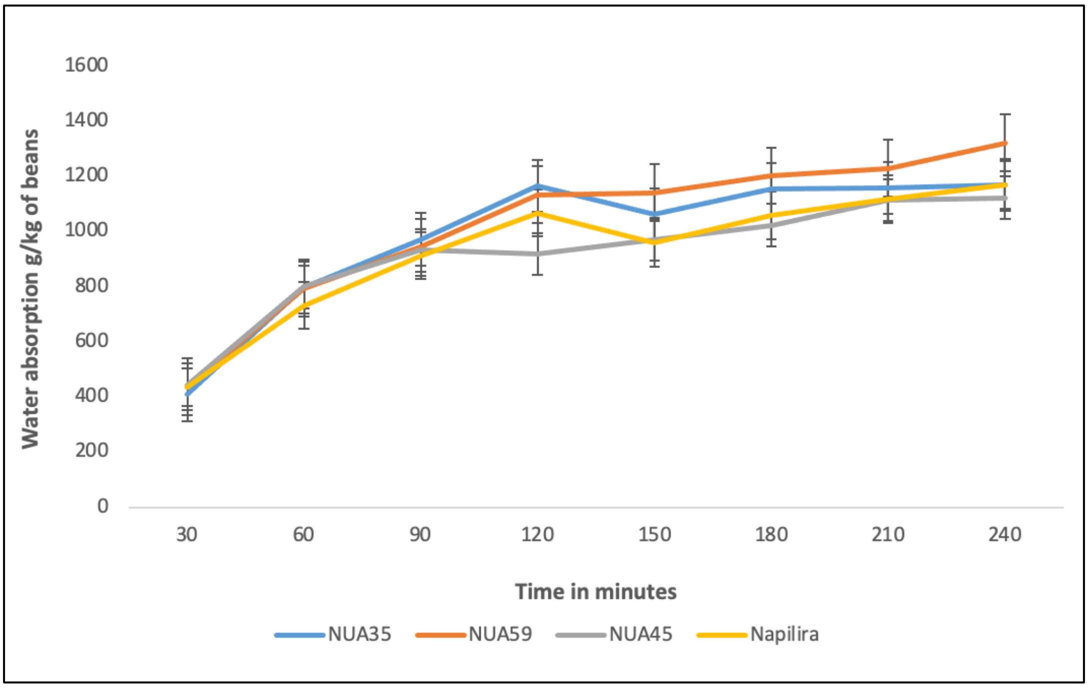
**Error bars that do not overlap indicates significant difference (P< 0.05)*

Figure 1: Graph showing water absorption during 6 hours of soaking beans.

Chewere (2010) reported that the hydration capacity of 10 varieties of beans ranges from 955 to 1245 after 24 hours of soaking. Also, Kang'ombe (2016) found the water absorption of dry Bambara groundnuts ranged from 9.8 to 529 g of kg/water. Water absorption of beans reported in this current study is slightly higher than what Kang'ombe (2016) documented. Water absorption of legumes is a measure of gross water uptake by seeds during soaking and is influenced by the integrity of the seed coat (Urga et al. 2006). Thick seed coats reduced water absorption during the first six hours of soaking. Agbo et al. (1987) also reported that the thickness of the seed coat palisade layer caused slow hydration rates due to the barrier created by the sheet of cells, appearing like bundles, to the fast movement of water through the cotyledon cells. High hilum length and open and large opening of the micropyle has been documented to increase rapid water absorption during soaking (Sefa-Dedeh and Stanley 1979).

Water absorption during cooking of beans

There was an increase in water absorption with increased cooking time, as shown in Figure 2 below. NUA 59 had the highest water absorption, and NUA45 having the lowest water absorption when cooked for 240 minutes. There were no significant differences in water absorption during cooking among the four varieties at p< 0.05.



Error bars that do not overlap indicates significant difference (P< 0.05)

Figure 2: Graph showing water absorption during cooking of beans for 4 hours.

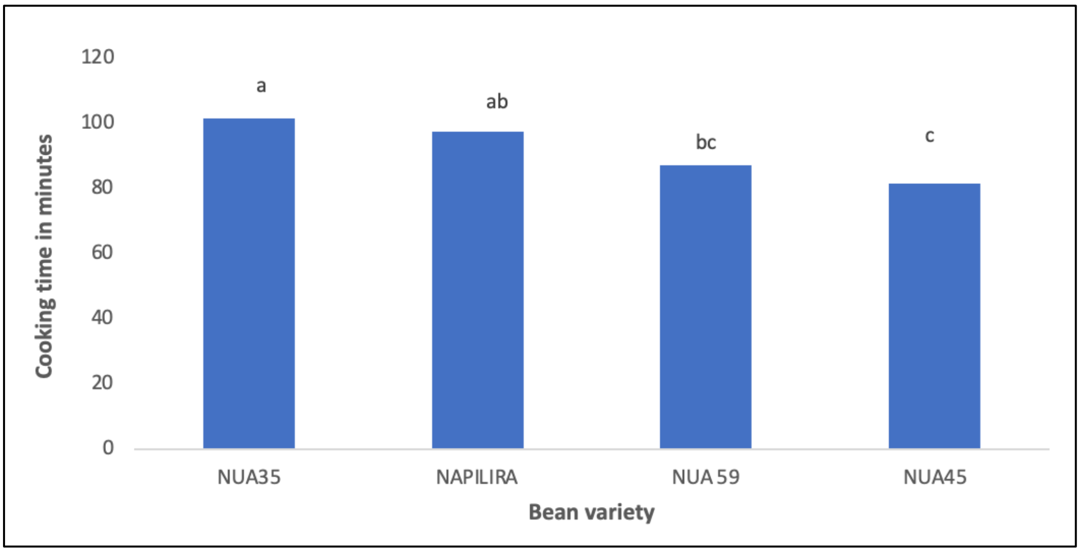
During the first 30 minutes, there was rapid initial water uptake observed for all varieties. The rapid rate was due to the filling of capillaries on the surface of the seed coat at the hilum (Hsu et al. 1983). NUA 59 had a high uptake of water during cooking, and this might be due to its thick seed coat compared to other varieties. At 150 minutes, there was a decrease in water absorption; this shows that NUA 35, NUA 45, NUA59, and Napilira reached the entire point hydration of gelatinized starch.

Cooking time of beans

Significant differences were observed (p0.017) in the cooking time of beans. NUA 35 took more time to cook (101 minutes), while NUA 45 and NUA 59 took less time to cook at 81 and 87 minutes, respectively. Chewere (2010) reported that the cooking time of bean varieties ranged from 60 to 89 minutes of BCMV B2 Kalima, Nasaka, BCM, V B4 and BCD/O 19. Mkanda (2007) studied six bean varieties grown in different locations in South Africa, cooking times varied from 42.4 to 97.8 minutes.

The findings of the present study are higher as compared to other studies. This might be attributed to the different bean varieties studied, physicochemical properties of the cotyledons, and the skin of the beans (Barros and Prudencio 2016). Cooking time has been defined as the time required for beans to reach the cooked texture considered acceptable to consumers (Moscoso, Bourne and 1984). Cooking time is more ideal because it is close to the texture that is preferred by consumers (Proctor and Watts 1987).   Cooking time in beans ranges from 45 minutes to 230 minutes depending on the variety, cooking medium, and method (Mwangwela 2000; Bean/Cowpea CRSP 1995; Shellie Dessert and Hosfield; 1990).

Consumers prefer beans that cook fast because it saves on energy costs and time to prepare meals. Well-cooked beans have a soft texture, and most consumers prefer them because they are easy to chew. Hence NUA 45 and NUA 59 are ideal bean varieties for saving energy and time.

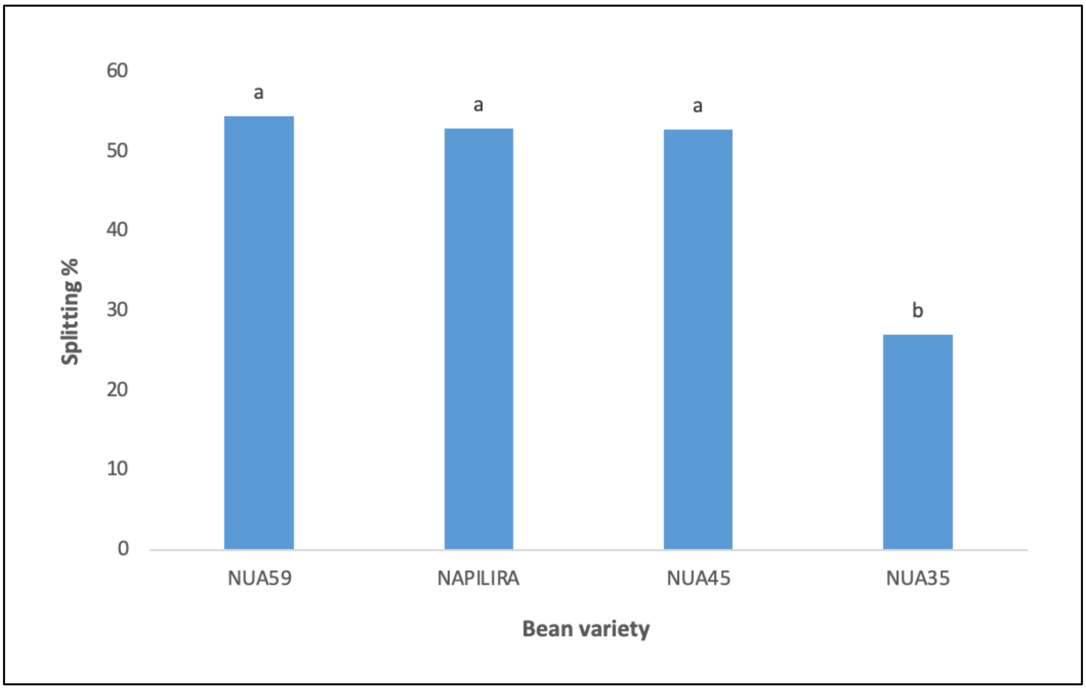


Different superscripts show significant differences p<0.05

Figure 3: Graph showing cooking time of the different bean varieties

Splitting percentage of beans

There were significant (p0.004) differences in the splitting percentage of the bean varieties. NUA59 recorded the highest value at 54.4%, while NUA35 recorded the lowest at 27.0%. There were no significant difference between NUA59, NUA45, and Napilira , while NUA 35 was different from the three bean varieties. Chewere (2010) found similar splitting percentages of seed coat and cotyledon (between 20 to 53.1 %) of beans. During cooking, the splitting percentage is affected by the seed coat thickness, seed density, texture of cooked beans, and calcium levels.



Different superscripts show significant differences p<0.05

Figure 4: Splitting percentage of the different bean varieties

Splitting indicates cotyledon softening; it is not always an indication that the seed is cooked (Taiwo 1998). Penicela (2010) observed that cowpeas with thick seed coats have a higher percentage of splitting than cowpeas with thin seed coats. Penicela (2010) reported that splitting in legume seeds is associated with high water absorption and the rate of splitting increases with increased cooking time. These findings of this study are contrary to what is reported with Kang'ombe (2016): an increase in water absorption during soaking and cooking, resulting in an increasing splitting percentage of Bambara groundnuts. It was observed that the NUA35 bean variety in this study absorbed more water during soaking and cooking, but it showed less splitting. NUA 59, NUA45, and Napilira showed a high percentage of splitting with less water absorption. The differences might be due to the genetic makeup of NUA35, which limits the splitting of this variety. NUA59, NUA45, and Napilira will be ideal in making chipere as compared to NUA35.

Soluble solid loss (broth thickness) during cooking of beans

The broth thickness varied among the varieties. Bean variety affected broth thickness ($p < 0.001$). Soluble solid loss of the beans in this study ranged from 4.87 to 11.83%. NUA59 had a high soluble solid loss (11.83 %), while Napilira was the lowest (4.87%). Yeung (2007) found that soluble loss of cowpea ranged from 7 to 14 %. The findings of this study are lower as compared to what Yeung (2007) reported.

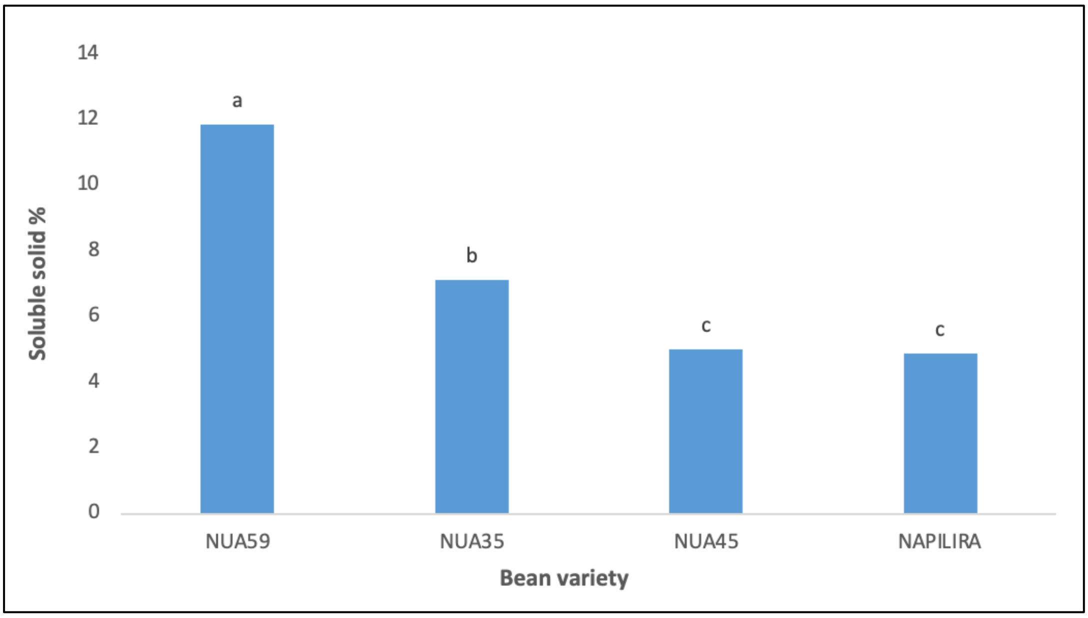


Figure 5: Soluble solid loss (broth thickness) during cooking of beans.

The thicker the broth in the NUA59 variety might be due to the higher amount of amylose leached out and stayed dispersed in the cooking water (Chewere, 2010). Broth thickness of beans happens due to leaching out of the soluble solids such as protein and starch from the seed. These soluble solids may form a gel that could thicken the water used during the cooking of beans. Wu (2002) reported that the high splitting percentage of beans during cooking results in the formation of a thick broth. The findings of Wu (2002) agree with the present finding. NUA59 had a high splitting percentage, and this resulted in a more soluble loss, therefore making the broth to be thick. But this theory did not work for NUA35, NUA45, and Napilira. NUA35 had a low splitting percentage, resulting in a thick broth compared to NUA45 and Napilira which were shown to have a high splitting percentage.

Consumer acceptability of beans

Demographic information

The majority of respondents were females (84%) because Africa RISING has fewer men farmers than females that were participating in the trials. A high percentage of respondents were aged between 40-50 years. Most of the participants were married (72 %). Most farmers' highest level of education was primary education, while farming was their main income-earning occupation (93.3 %). The annual income for a majority of the farmers ranged between 50,000 - 90,000 Malawi Kwacha after selling their field harvest (32.7%). Those with a total income above 100,000 Malawi Kwacha were 26.7 %.

Table 2: Demographic characteristics of panelist

Characteristic	Frequency	Percentage
Sex		
Male	24	16
Female	126	84
Age		
20-30	28	18.7
31-39	37	24.7

40-50	40	26.7
51-59	16	10.7
above 60	24	16.7
Marital status		
Married	108	72
Divorced	15	10
Single	1	0.67
Widow/widower	26	17.33
Education level		
Primary	106	70.67
Secondary	8	5.33
Adult literacy	1	0.67
None	35	23.33
Occupation		
Farmer	140	93.33
Business	1	0.67
Farmer and casual labor	2	1.33
Farmer and business	5	3.33
Live with parents	1	0.67
Employed officer	1	0.67
Annual income		
10,000 - 20,000	33	22
21,000-29,000	5	3.33
30,000-40,000	18	12
41,000 - 49,000	6	4
50,000 - 99,000	49	32.67
100,000 above	37	24.67
Don't know	2	1.3

Consumption frequency of biofortified beans

The consumption frequency data of biofortified beans were collected. All the respondents in this study consume common beans. A higher percentage (82 %) of the respondents have ever consumed bio-fortified beans, while only 18 % have cultivated bio-fortified beans for the first time and had not yet consumed the beans. Farmers with access to biofortified beans majority consume them at least once a week while others did so more than once a week, and yet others consume them once a month.

A higher percentage of respondents (27.3 %) had consumed bio-fortified beans the previous month, while 22.7 % of respondents had consumed bio-fortified beans in the previous week. The taste was the most-liked attribute of bio-fortified beans at 38 %, followed by smell at 12%. Other attributes that were liked included color, smell and taste accounted for 6, 12, and 38 percentages, respectively. The ease of cooking was another important attribute. This is the one major factor that respondents consider when purchasing beans to save resources such as firewood. Other respondents (20 %) consider the color of beans, while others consider color and easy to cook (25 %). A fewer percentage (10 %) consider grain size, color, and ease of cooking when purchasing beans for consumption. The consumption patterns showed that the respondents were already familiar with bio-fortified beans.

Table 3: Consumption patterns of bio-fortified beans

Variable	Category	Frequency	Percentage
Consumption frequency of Bio-fortified beans	Once a week	46	30.7
	Once a month	29	19.3
	N/A	27	18.0
	others	48	32.0
The last time I consumed Bio-fortified beans	A week ago	34	22.7
	A month ago	41	27.3
	More than six months ago	26	17.3
	More than a year	6	4.0
	Others	16	10.7
	N/A	27	18.0
Attributes liked on Bio-fortified beans	Color	9	6.0
	Smell	19	12.7
	Taste	58	38.7
	color, smell, and taste	15	10.0
	Color and Smell	3	2.0
	Color and Taste	4	2.7
	Smell and Taste	14	9.3
	N/A	27	18.0
Factors considered when purchasing beans	Grain size	7	4.7
	Color	30	20.0
	Easy to cook	43	28.7
	Grain size and color	6	4.0
	Grain size and easy to cook	6	4.0
	Color and easy to cook	38	25.3
	Grain size, color, and easy to cook	16	10.7

Consumer acceptability using CATA methodology

The appearance of cooked beans

The color was not significant among the four varieties p (0.993). Napilira and NUA 59 appeared to be more brownish compared to NUA 35 and NUA 45. The brown colour in the bean seed coat is associated with the availability of phenolic compounds and flavonoids (Machinjili, 2018). This is attributed to the dark colour of beans when cooked. NUA 59 was rated to be shinier, while NUA 35 was dull in appearance. Splitting, size, broth, and seed coat attributes were significantly different among the four varieties tasted by consumers

The greater proportion of respondents described NUA 59 bean variety as a shiny, extensive, split bean variety with a peeled seed coat and a dense broth when cooked. These findings are similar to the cooking characteristics obtained earlier during laboratory analysis, as shown in figures 4 and 5 above. NUA 59 had a high splitting percentage and thick broth while NUA 35 was the lowest in splitting percentage, but the broth was thick compared to NUA 45 and Napilira. NUA 35 was second in broth viscosity after NUA 59 was rated as thick by panelists, as shown in Table 4 below. This also agrees with data from the laboratory, which showed NUA 35 broth to be thicker than NUA 45 and Napilira. According to Rios et al. (2002), consumers prefer lighter-colored beans because they relate darker colors to old, hard beans that require more time to cook, generating increased energy expenditure. Beans with more number splits are associated with peeled seed coats (Mkanda, 2007). This relationship is observed with NUA 59. It was split, and it had peeled seed coats (Table 4). The presence of minerals in bean seed coat affects the splitting during cooking (Wu et al. 2005). The less splits in NUA 35 bean variety might be attributed to high concentrations of Calcium, iron, and Sodium in the seed coat.

Table 4: Cochran's Q test for each attribute assessed

Attributes	NUA 35	NUA45	NAPILIRA	NUA 59	p-values
Brownish/Red	**0.643^{a}**	**0.643^{a}**	**0.652^{a}**	**0.652^{a}**	**0.993**
Shiny	0.317^{a}	0.313^{a}	0.370^{ab}	0.439^{b}	0.009
Dull	0.322^{ab}	0.335^{b}	0.278^{ab}	0.204^{a}	0.008
Splitted	0.109^{a}	0.361^{b}	0.404^{bc}	0.522^{c}	0.000
Not Splitted	0.522^{c}	0.270^{b}	0.230^{b}	0.130^{a}	0.000
Big	0.287^{a}	0.300^{a}	0.361^{a}	0.622^{b}	0.000
Medium	0.030^{a}	0.013^{a}	0.026^{a}	0^{a}	0.05
Small	0.322^{b}	0.304^{b}	0.265^{b}	0.022^{a}	0.000
Peeled seed coat	0.039^{a}	0.139^{b}	0.217^{b}	0.352^{c}	0.000
Unpeeled seedcoat	0.600^{c}	0.50^{bc}	0.430^{b}	0.287^{a}	0.000
Liquidity broth	0.387^{b}	0.570^{c}	0.517^{c}	0.026^{a}	0.000
Viscous broth	0.248^{b}	0.074^{a}	0.122^{a}	0.617^{c}	0.000
Cooked bean Aroma	0.270^{a}	0.326^{ab}	0.413^{b}	0.626^{c}	0.000
Raw bean Aroma	0.370^{c}	0.317^{bc}	0.230^{b}	0.013^{a}	0.000
Burnt Aroma	**0.030^{a}**	**0.026^{a}**	**0.013^{a}**	**0.013^{a}**	**0.427**
Metallic Aroma	**0.035^{a}**	**0.035^{a}**	**0.052^{a}**	**0.013^{a}**	**0.11**
Sweet taste	0.117^{a}	0.222^{bc}	0.148^{ab}	0.283^{c}	0.00
Bitterness taste	0.030^{a}	0.004^{a}	0.009^{a}	0^{a}	0.009
Salty taste	**0.413^{a}**	**0.417^{a}**	**0.461^{a}**	**0.461^{a}**	**0.509**
Old Grain taste	0.417^{c}	0.330^{bc}	0.300^{b}	0.178^{a}	0.00
New Grain taste	0.222^{a}	0.300^{ab}	0.343^{bc}	0.461^{c}	0.00
Burnt taste	**0.048^{a}**	**0.022^{a}**	**0.026^{a}**	**0.030^{a}**	**0.32**
Cooked Bean Taste	0.274^{a}	0.330^{ab}	0.439^{b}	0.626^{c}	0.00
Raw bean taste	0.361^{c}	0.300^{bc}	0.209^{b}	0.009^{a}	0.00
Metallic Feeling/taste	0.074^{b}	0.057^{ab}	0.052^{ab}	0.013^{a}	0.013
Soft	0.226^{a}	0.326^{ab}	0.452^{b}	0.639^{c}	0.000
Hard	0.422^{c}	0.330^{c}	0.196^{b}	0.013^{a}	0.000
Tough	0.483^{c}	0.391^{bc}	0.330^{b}	0.087^{a}	0.000
Fragile	0.148^{a}	0.222^{ab}	0.317^{b}	0.561^{c}	0.000
Mushy	0.078^{a}	0.226^{b}	0.317^{b}	0.578^{c}	0.000
Stiff	0.522^{c}	0.387^{b}	0.291^{b}	0.065^{a}	0.000
Grainy	0.357^{c}	0.243^{b}	0.183^{b}	0.026^{a}	0.000
Smooth	0.291^{a}	0.400^{ab}	0.470^{b}	0.626^{c}	0.000
Juicy	0.113^{a}	0.243^{b}	0.304^{b}	0.474^{c}	0.000
Dry	0.435^{c}	0.322^{b}	0.248^{b}	0.104^{a}	0.000

The aroma of cooked beans

Cooked beans and raw beans aroma were significant p (0.05), while burnt and metallic aroma was not different among the bean varieties shown in the table below. A higher proportion of the respondents in this study rated NUA 59 as associated with cooked bean aroma (0.626), while NUA 35 was rated to have uncooked beans (0.370). Cooked bean aroma is due to Strecker degradation, which is a chemical reaction. This process involves amino acids reacting with a carbonyl 1 compound to form ketones, aldehyde, and other volatile compounds (Rizzi*,* 2008). The more the amino acids and carbonyl groups in a bean variety, the more volatile compounds are produced, resulting in higher aroma intensity (Chewere, 2010).

Taste attribute of cooked beans

There were significant differences in sweet, bitter, grain (new and old), cooked bean, raw, cooked bean, and metallic taste. The salty and burnt taste was not different among the varieties. NUA 59 exhibited high sweetness, new grain taste, and cooked bean taste, while NUA 35 had a bitter taste, old grain taste, raw bean taste, and metallic taste (table 4 above). Sucrose is the major sugar in legumes, unlike cereals (Ihekoronye and Ngoddy 1985). Phenolic compounds and mineral content affect the taste. The higher mineral content/phenolic compound of beans (e.g. iron) causes the consumers to notice the beans to be bitter, and this might be the case of NUA 35, which was reported to be bitter. Mkanda (2007) also reported that thermal heat treatment impacts starch gelatinization and complex sugars break down to simple sugars such as glucose and fructose, bringing about desirable flavors such as the sweet taste of cooked beans.

Texture attribute of cooked beans

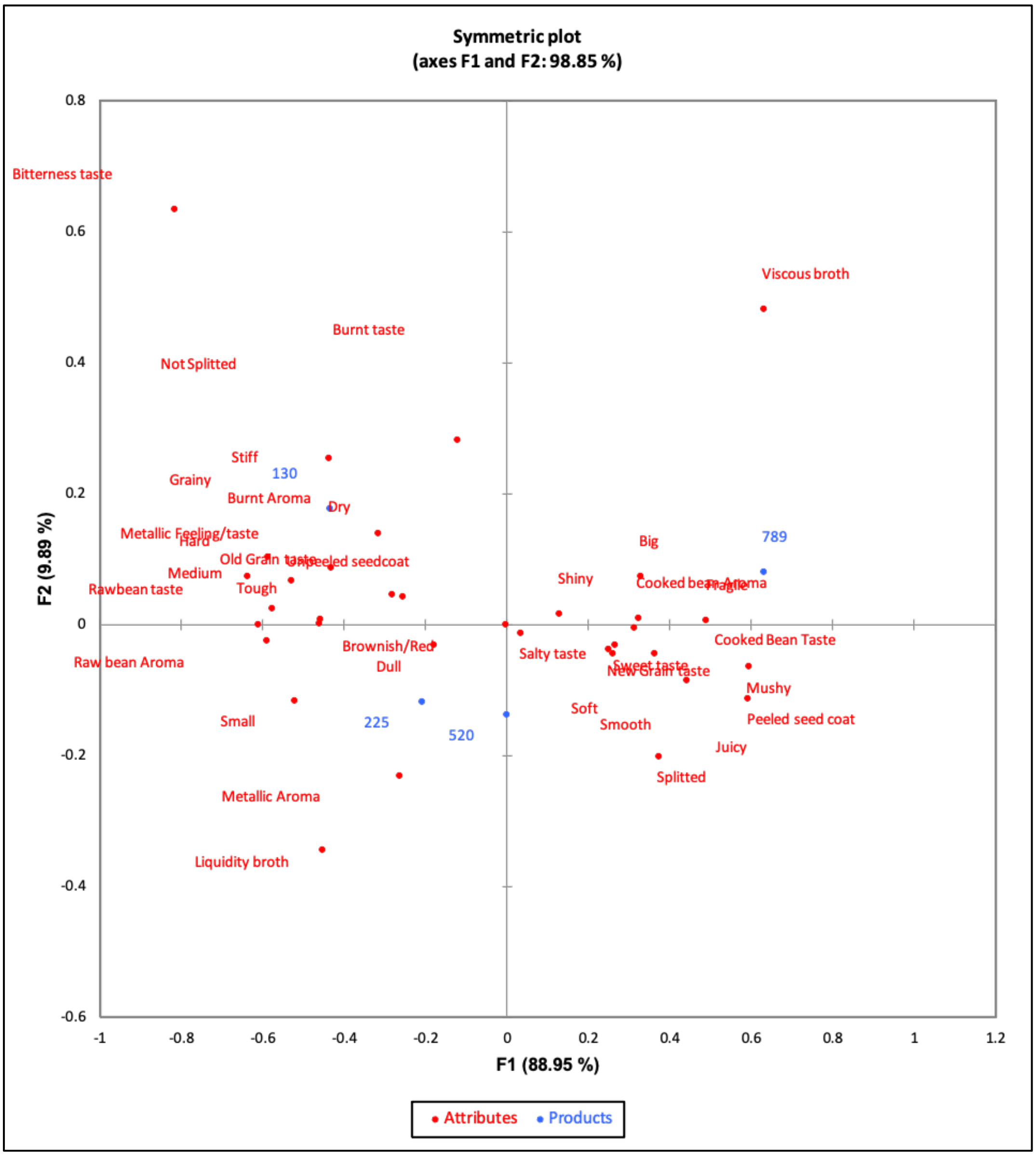
All texture attributes were significantly different p (0.000) among the varieties used in this study. Respondents identified the following attributes for NUA 59 bean variety - soft, mushy, fragile seed coat, smooth and juicy; while NUA 35 was characterized as hard, tough seed coat, stiff, grainy and dry. If the beans' cell walls were rigid, swelling and dispersion of starch during cooking is inhibited, rendering the cooked beans to be hard in texture (Wang et al., 2003). During cooking, water uptake could also be affected by differences in the rate of starch gelatinization, nature, and amounts of non-starch constituents (such as protein) that may cause a barrier to swelling of starch granules (Deshpande and Cheryan 1986), resulting in hard textured cooked beans. Seed coat residues in the mouth were experienced in the hard textured beans, which could be attributed to tougher seed coats that take long to disintegrate during chewing.

Table 5: Consumer liking of bean varieties using a five-point hedonic scale

Bean variety	Liking
NUA 59	4.913 a
Napilira	3.993 b
NUA 45	3.696 b
NUA 35	3.034 c
P-value	< 0.0001

Consumer liking of cooked bean varieties

Consumers/respondents were asked to rate the liking for every bean tasted using a five-point hedonic scale. The majority liked NUA 59, followed by Napilira, and lastly, the least preferred was NUA 35. Mkanda (2007) reported that varieties with the most split beans, soft and mushy, were more acceptable by consumers, hence the high liking of NUA 59 by consumers compared to other bean varieties. The results of this study are in agreement with Mkanda (2007), who assessed the relationship of consumer preferences to sensory and physicochemical properties of dry beans, which found that beans rated lowly in liking was a result of hard texture and appearance. The bean varieties described by the descriptive sensory panel as sweet, having cooked bean flavors, and soft textures (Jenny-MP, Kranskop and PAN 148) were preferred by consumers. On the contrary, those varieties that were described as hard in texture, split and having raw bean flavors, bitter, soapy and metallic feeling in the mouth (Mkuzi-MP, AC Calmont-MP, FS PAN 150-MP and Jenny-FS) were the least preferred.



Note*: 789: NUA 59, 225: NUA 45,520: Napilira, 130: NUA 35*

Figure 6: Score plot showing relatedness of bean samples rating to sensory characteristics

The symmetric plot is shown above (figure 6) shows the association of products, attributes, and the closeness of the samples. The first two principal components explained 98.85% of the variation in bean samples. There was a high variance in PC1 and PC2, which showed high systematic variation within the data. This indicates that respondents discriminated well between the samples. For PCA to be significant, at least 50 % cumulative variance has to be explained (Arvanitoyannis, Mavromatis, Rodiatis and Goulas 2007). NUA 59 and NUA 35 were observed with no closeness in their sensory attributes, while NUA 45 and Napilira were close (they are associated with the same sensory attributes). The PCA explains how respondents rated each sample and its attributes related to a particular sample. PC1 accounted for 88.95 %, which shows NUA 59 is associated with viscous broth, big, shiny, softness and cooked bean aroma, sweetness split, and peeled seed coat. PC2 explains the difference (9.89) in NUA 35, NUA 45, and Napilira. NUA 35 is associated with bitterness, hardness, not split, burnt aroma, metallic taste, grainy and raw cooked bean aroma/taste. Figure 7 below is showing the association of liking and attributes.

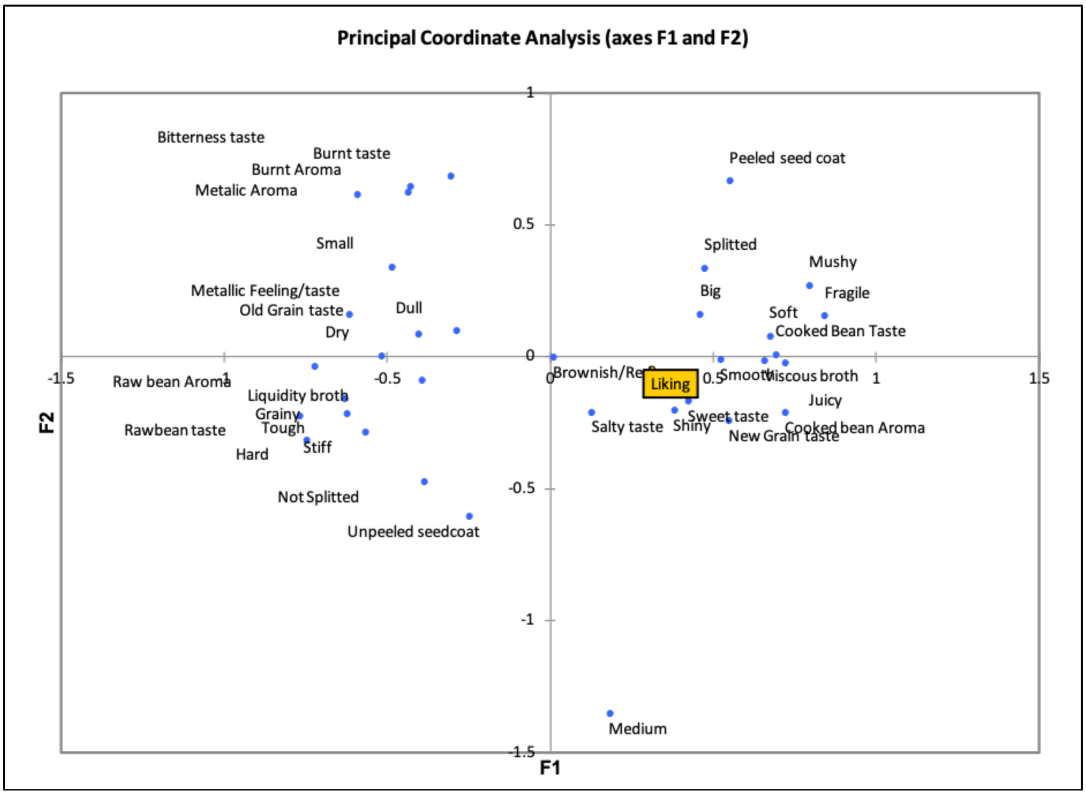


Figure 7: Association of Liking and Attributes

This study showed that bean varieties that are liked are associated with the following attributes: peeled seed coat, split, mushy, big, soft, fragile seed coat cooked bean aroma/taste, viscous broth, new grain taste, and salty brownish. In this case, NUA 59 was associated with these attributes. Hence it had high liking/preference by consumers. Figure 8 below shows the mean impact of significant attributes on liking. The color of bean variety (brownish /red) had the highest mean impact, and grainy attribute had the lowest mean impact. This means that beans with brown color will be more liked than those with grains (more grains remaining in month). These attributes need to be considered when breeding new bean varieties.

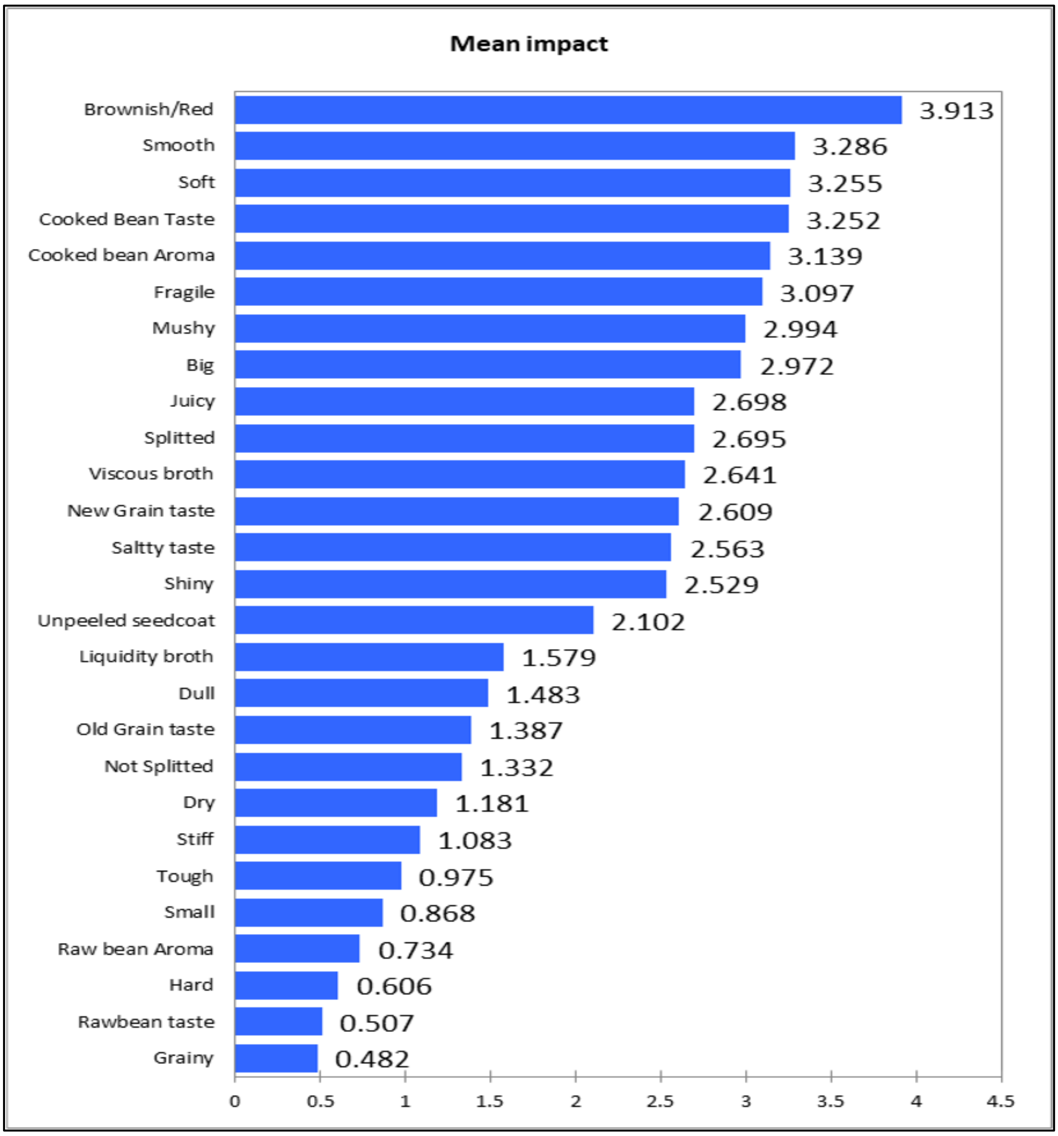


Figure 8: Mean impact of significant attributes on the liking of beans

Conclusion

Moisture content, water absorption during soaking and cooking did not differ in terms of variety. The cooking time, splitting percentage, and soluble solid loss varied with bean variety. NUA45, NUA59, and Napilira had a short cooking time and high splitting percentage, indicating good texture and taste quality. NUA35 should be soaked first before cooking to reduce cooking time, hence saving energy and time. NUA 59 was the most preferred variety due to its softness, cooked bean aroma, cooked bean taste, split, shiny, mushy, and juiciness. Napilira was second, followed by NUA 45 and NUA 35, respectively.

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